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Biofeedback as a form of neurorehabilitation in Parkinson's disease

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SUMMARY

Parkinson's disease is a degenerative disease of the nervous system. An important element in the treatment of the disease is neurorehabilitation. One of the forms of neurorehabilitation may be biofeedback. The above technique uses electronic devices that allows an individual to learn how to change the body's function in order to reduce the clinical symptoms of the disease and improve health. Previous studies have confirmed that biofeedback has a beneficial effect on the health of patients with Parkinson's disease. The aim of the work was a review of the literature on biofeedback as a form of neurorehabilitation in this disease.

Key words: Parkinson's disease, neurorehabilitation, biofeedback

INTRODUCTION AND PURPOSE OF WORK

Parkinson's disease (PD) is a progressive neurodegenerative disorder. Resulting from a pathophysiologic loss or degeneration of dopaminergic neurons in the *substantia nigra* of the midbrain and the development of neuronal Lewy Bodies, idiopathic PD is associated with risk factors including aging, family history, pesticide exposure and environmental chemicals. Its ultimate causes are unknown. Characterized by both motor and non-motor symptoms, PD patients classically display rest tremor, rigidity, bradykinesia, and stooping posture. Non-motor symptoms are classified as neuropsychiatric, autonomic, sleep, and sensory. PD can be associated with depression, anxiety, dementia, orthostasis and hyperhidrosis. There are many medical options for the treatment of PD but levodopa remains the mainstay. Deep brain stimulation and other advanced therapies are also available. However, definitive disease-modifying therapy is still lacking (1,2).

The biofeedback methods used in rehabilitation are based on biomechanical measurements and measurements of the physiological systems of the body. The physiological systems of the body which can be measured to provide biofeedback are the neuromuscular system, the respiratory system and the cardiovascular system. Neuromuscular biofeedback methods include electromyography (EMG) biofeedback and real-time ultrasound imaging biofeedback. EMG biofeedback is the most widely investigated method of biofeedback and appears to be effective in the treatment of many musculoskeletal conditions and in post cardiovascular accident rehabilitation. Measurements of movement, postural control and force output can be made using a number of different devices and used to deliver biomechanical biofeedback. Inertial based sensing biofeedback is the most widely researched biomechanical biofeedback method, with a number of studies showing it to be effective in improving measures of balance in a number of populations. Other types of biomechanical biofeedback include force plate systems, electro goniometry, pressure biofeedback and camera based systems however the evidence for these is limited. Biofeedback is generally delivered using visual displays, acoustic or haptic signals, however more recently virtual reality or exergaming technology have been used as biofeedback signals (3).

The aim of the work was a review of the literature on biofeedback in PD.

BIOFEEDBACK IN PARKINSON'S DISEASE - *REVIEW OF THE LITERATURE*

The β-band oscillation in the subthalamic nucleus (STN) is a therapeutic target for PD. Previous studies demonstrated that l-DOPA decreases the β-band oscillations with improvement of motor symptoms. It was hypothesized that neurofeedback training to control the β-band power in the STN induces plastic changes in the STN of individuals with PD. Fukuma et al. recorded the signals from STN deep-brain stimulation electrodes during operations. Four patients were induced to decrease the β-band power during the feedback training (down-training condition), whereas the other patients were induced to increase (up-training condition). The authors concluded that the patients could voluntarily control the β-band power in STN in the instructed direction through neurofeedback (4).

Szydlowski et al. (5) observed the effects of a rehabilitation program with an audio-biofeedback technology device called Electroskip in a patient with PD. The patient completed a 6-week rehabilitation program focused on functional tasks, balance and gait training while using Electroskip technology, which is a wireless, wearable device that sends a discrete real-time generative audio-biofeedback signal when the user steps on either the heel or toe force sensors positioned under the innersoles. The outcome measures included the Timed Up and Go test, the modified Gait Abnormality Rating Scale, the modified Parkinson's Activity Scale, and the Freezing of Gait Questionnaire. Clinically significant improvements were seen in all measures at 6 weeks. The results of this report suggest that a rehabilitation program focused on functional tasks, balance, and gait training using the Electroskip technology may be beneficial for improving gait and balance in a patient with moderate PD.

Carpinella et al. (6) analyzed the feasibility and efficacy of a novel system Gamepad for biofeedback rehabilitation of balance and gait in PD. Assessments were performed by a blinded examiner preintervention, postintervention, and at 1-month follow-up. Primary outcomes were the Berg Balance Scale (BBS) and 10-m walk test. Secondary outcomes included instrumental stabilometric indexes and the Tele-healthcare Satisfaction Questionnaire. Gamepad-based training was feasible and superior to physiotherapy without feedback in improving BBS performance and retaining it for 1 month.

In the study of Lavermicocca et al. (7) the NeuroSky MindWave headset and related software were used as Brain-Computer Interfaces. Cognitive revaluation showed a significant increase in scores and satisfaction questionnaires reported high values. The application of neurofeedback techniques in PD patients was promising. The increase in satisfaction levels seems to be due to the perception of a direct control over one's cognitive performances.

The purpose of the study conducted by Lee et al. (8) was to explore the effects of two coding schemes (binary versus continuous) for vibrotactile biofeedback during dynamic weight-shifting exercises that are common physical therapists' recommended balance exercises used in clinical settings. All participants performed dynamic weight-shifting exercises assisted with either the binary or continuous vibrotactile biofeedback delivered using with vibrating actuators (tactors) in either the anterior-posterior or medial-lateral direction. The continuous coding scheme produced significantly better performance than the binary scheme when both groups were performing dynamic weight-shifting balance exercises with assistive vibrotactile biofeedback.

In the study conducted by Caudron et al. (9) the PD patients performed sequences of pull-tests, either with eyes open, eyes closed or visual biofeedback, crossed with the verbal instruction to focus either on the stabilization or on the vertical body orientation. With eyes open and eyes closed, patients did not recover their initial vertical orientation by adopting a slightly tilted backward position. This bias disappeared with the visual biofeedback. Moreover, falls consecutive to the test were significantly less frequent with the visual biofeedback than in the two other visual conditions. These different orientation and stabilization parameters were not affected by the instruction.

Mirelman et al. (10) based on the observation that postural control improved in patients with vestibular dysfunction after audio-biofeedback training, tested the feasibility and effects of this training modality in patients with PD. The training was individualized to each patient's needs and was delivered using an audio-biofeedback system with headphones. A significant improvement of balance, as assessed by the Berg Balance Scale, was observed, and a trend in the Timed up and go test was also seen. In addition, the training appeared to have a positive influence on psychosocial aspects of the disease as assessed by the PD quality of life questionnaire (PDQ-39) and the level of depression as assessed by the Geriatric Depression Scale.

Nanhoe-Mahabier et al. (11) investigated the effect of artificial vibrotactile biofeedback on trunk sway in PD. Overall, patients in the feedback group had a significantly greater reduction in roll and pitch sway angular velocity. Moreover, roll sway angle increased more in controls after training, suggesting better training effects in the feedback group. In conclusion, one session of balance training in PD using a biofeedback system showed beneficial effects on trunk stability.

Schalling et al. (12) studied the effects of biofeedback on voice sound level (SL) in subjects with reduced voice SL, secondary to PD, using a portable voice accumulator. Voice SL, phonation time, and level of background noise were registered with a portable voice accumulator during three consecutive registration periods. Biofeedback, in the form of a vibration signal when voice SL went below an individually set threshold level, was administered during the second registration period only. There was a statistically significant increase in voice SL during the period when biofeedback of voice SL was administered.

Azarpaikan et al. (13) studied the effect of a neurofeedback training period on balance problems associated with PD. Prior to and after training, pre-tests and post-tests of static and dynamic balance were administered using "limit of stability" for the Biodex as well as the Berg scale. The results revealed that, after neurofeedback training, a statistically significant improvement in both static and dynamic balance in the experimental group was achieved.

The aim of the study conducted by Rossi-Izquierdo et al. (14) was to assess effectiveness of balance training with a vibrotactile neurofeedback system in improving overall stability in patients with PD. Individualization of the rehabilitation program started with a body sway analysis of stance and gait tasks (Standard Balance Deficit Test, SBDT) by using the diagnostic tool of the applied device (Vertiguard(®)-RT). Improvement of postural stability was assessed by performing SBDT, Sensory Organization Test (SOT) of Computerized Dynamic Posturography (CDP), Dizziness Handicap Inventory (DHI), Activity-specific Balance Confidence (ABC) scale and recording the number of falls over the past three months. After neurofeedback training (NFT), there was a statistically significant improvement in body sway, number of falls, and scores of SOT, DHI and ABC. In comparison with CDP-training, a statistically significant higher increase of SOT score was observed for patients after NFT with the Vertiguard-RT device compared to CDP training. The results showed that a free-field vibrotactile NFT with Vertiguard(®)-RT device can improve balance in PD patients in everyday life conditions very effectively, which might led in turn to a reduction of falls.

The objective of the pilot randomized clinical trial conducted by van den Heuvel et al. (15) was to investigate whether a balance training program using augmented visual feedback (VFT) is feasible, safe, and more effective than conventional balance training in improving postural control in patients with PD. Standing balance, gait, and health status were assessed at entry, at six weeks, and at twelve weeks follow-up. VFT proved to be a feasible and safe approach to balance therapy for patients with PD. In this proof-of-concept study VFT was not superior over conventional balance training although observed trends mostly favored VFT. These trends approached clinical relevance only in few cases: increasing the training load and further optimization of VFT may strengthen this effect.

The small randomized clinical trial evaluated if visual and kinematic feedback provided during supervised gait training would interfere or enhance mobility, endurance, balance, strength and flexibility in older individuals greater than one year post stroke or PD. Across all subjects, by diagnosis (stroke and PD) and by training group (control and experimental), there were significant gains in mobility (gait speed, step length, endurance, and quality), balance (Berg Balance), range of motion and strength. In summary, during supervised gait training, dynamic visual kinematic feedback from wireless pressure and motion sensors had similar, positive effects as verbal, therapist feedback. The authors concluded that a wireless kinematic feedback system could be used at home, to provide feedback and motivation for self-correction of gait while simultaneously providing data to the therapist (16).

Kotani et al. (17) tested whether the core exercise using the hybrid assistive limb lumbar type for care support (HAL-CB02) may improve the motor functions in frailty patients with or without PD. The participants performed core exercise and squats using HAL-CB02 for five sessions a week. Outcome measures were 10-m walking test, step length, timed up-and-go test, 30-s chair stand test, and visual analog scale. Evaluation was conducted at baseline, post-exercise, and 1- and 3-month follow-ups. Both PD and non-PD patients showed significant improvement in all evaluation items post-exercise. The results suggest that biofeedback exercise with HAL-CB02 is a safe and promising treatment for frailty patients. Motor dysfunction in PD patients may be partly due to physical frailty, and biofeedback exercise with HAL-CB02 is proposed as a treatment option.

Harrington et al. (18) presented a novel, wearable prototype of tactile biofeedback to alleviate gait disturbances, such as freezing of gait in PD. The authors designed and tested a phase-dependent tactile biofeedback system that can be easily worn on the feet, with a simple switch to turn it on or off. Preliminary validation was performed in 8 subjects with PD who show freezing during a turning in place test. A metronome, control condition was used to compare effectiveness in alleviating freezing. Promising results were obtained, both in term of acceptability of the device, and improving motor performance.

Govil et al. (19) used a closed-loop force feedback system to investigate the effect of altering proprioceptive feedback on EEG and resting tremor in PD. A velocity dependent counterforce simulating viscous friction was provided by haptic robots with simultaneous recording of kinematics, EMG and EEG while a patient was on and off dopaminergic medication. The authors were able to reduce the amplitude of the tremor. They also showed that force feedback shifts the center of EEG-EMG coherence posteriorly toward the somatosensory regions, which may have ramifications for noninvasive therapies.

Hypokinetic dysarthria (HD) is a common symptom of PD which does not respond well to PD treatments. Brabenec et al. (20) investigated acute effects of repetitive transcranial magnetic stimulation (rTMS) of the motor and auditory feedback area on HD in PD using acoustic analysis of speech. The results demonstrated that low-frequency stimulation of the temporal auditory feedback area may improve articulation in PD and enhance functional connectivity between the superior temporal gyrus ST and the cortical region involved in an overt speech control.

A systematic review was performed by Kearney et al. (21) to evaluate the effectiveness of augmented visual feedback-based treatments for motor rehabilitation in PD. Eight single-group studies and 10 randomized control trials were included in the review. Augmented visual feedback-based treatments resulted in improved outcomes with small to large effect sizes post-treatment for the majority of impairment, activity, participation, and global motor function measures, and these improvements were often superior to traditional rehabilitation/education programs. Augmented visual feedback appears to be a useful motor rehabilitation tool in PD.

Linden et al. (22) described a role of real-time functional magnetic resonance imaging (fMRI) neurofeedback in motor neurorehabilitation. Using fMRI to monitor the aspects of task-related changes in neural activation or brain connectivity, investigators can offer feedback of simple or complex neural signals/patterns back to the participant on a quasireal-time basis [real-time-fMRI-based neurofeedback (rt-fMRI-NF)]. The development of rt-fMRI-NF has been used to promote self-regulation of activity in several brain regions and networks. In PD and stroke, rt-fMRI-NF has been demonstrated to alter neural activity after the self-regulation training was completed and to modify specific behaviours.

CONCLUSION

Biofeedback is one of the forms of neurorehabilitation in PD. According to the literature, it can have a positive effect on patients' health by reducing the symptoms of the disease.

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